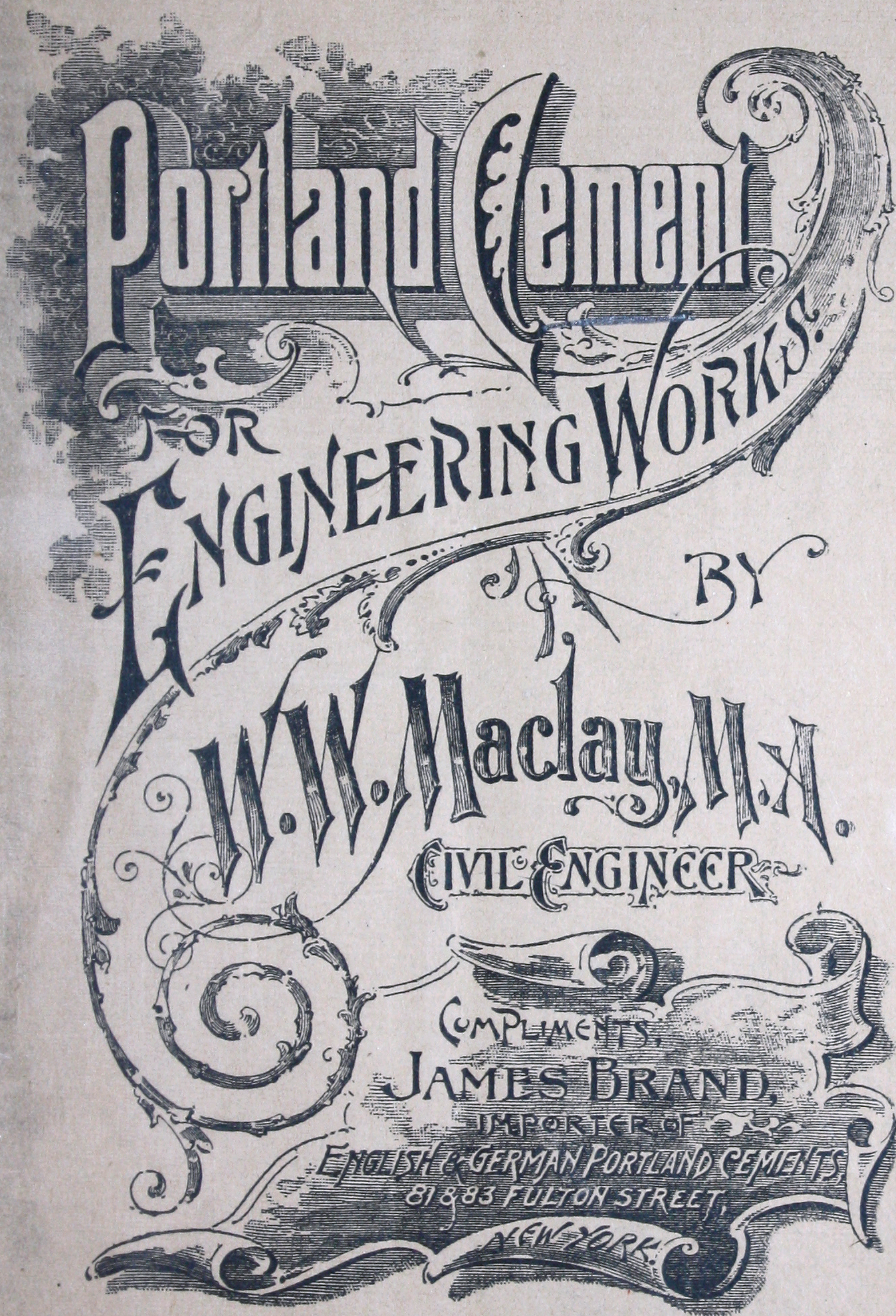
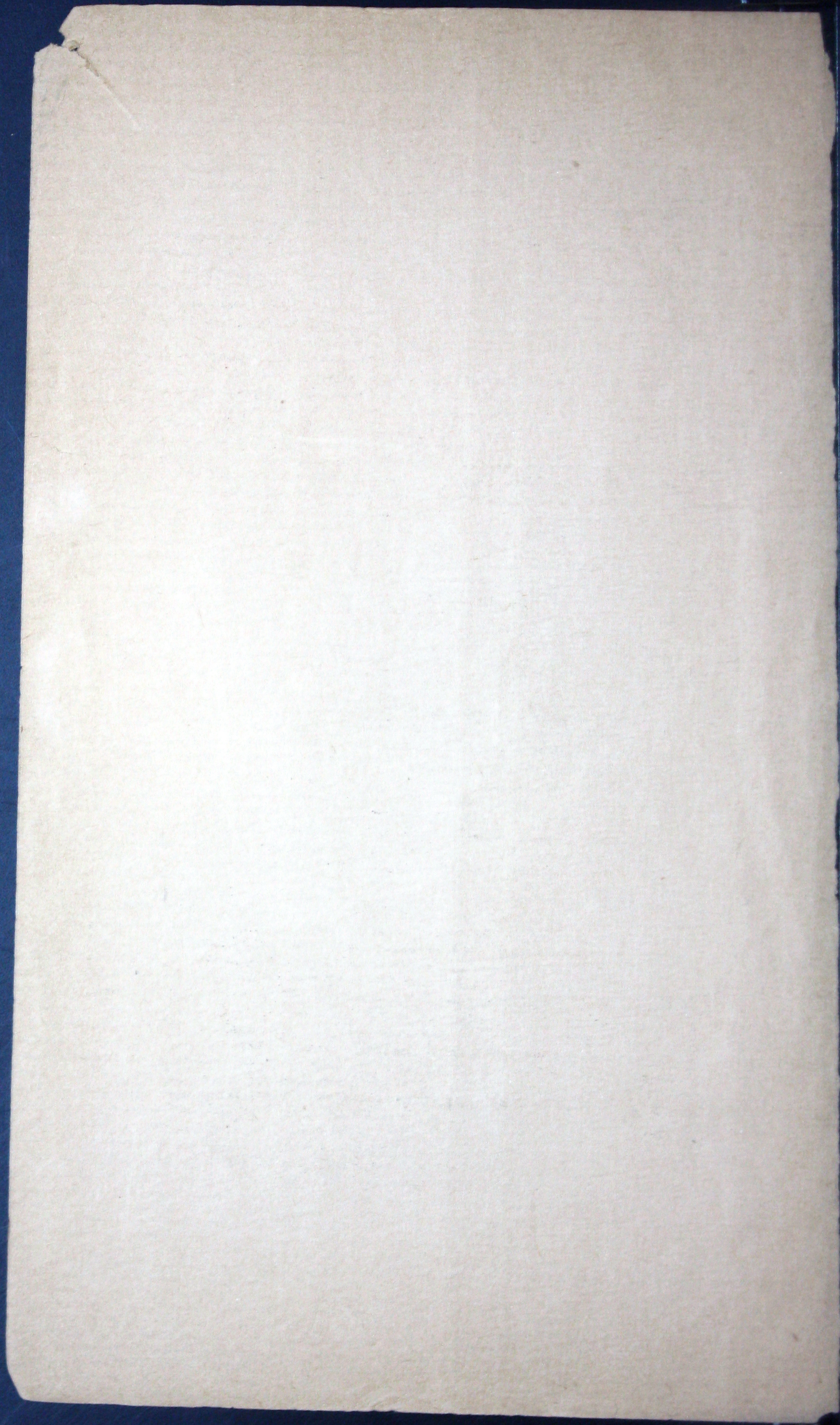


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PORTLAND CEMENT

—FOR—

ENGINEERING WORKS,

—BY—

CAPT. W. W. MACLAY, C. E.

COMPLIMENTS,

JAMES BRAND,

—IMPORTER OF—

ENGLISH & GERMAN PORTLAND CEMENTS,

81 & 83 FULTON STREET,

—NEW YORK—

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—BY—

WILLIAM WALTER MACLAY.

PREFACE.

The object of this pamphlet, written by an able authority, is to place before the Architects, Engineers, and Directors of Concrete works, the latest facts and experiments with PORTLAND CEMENT, and to facilitate the selection of good material.

The co-operation of those directly in charge of Concrete work, and the more general use of a Chemical Analysis and testing machine, are earnestly desired, to advance the quality of this useful material and to encourage those whose efforts have been to obtain high quality.

JAMES BRAND.

PORTLAND CEMENT

FOR

ENGINEERING WORKS.

SINCE the discovery of Portland Cement by Joseph Aspdin, bricklayer, of Leeds, in the county of York, England, a little over half a century ago, its effect in advancing the manufacture of hydraulic mortars and concretes has been almost magical. Engineering works of the greatest difficulty and magnitude are now of every-day occurrence, their success depending almost entirely upon the use of Portland Cement. In the old reign of lime and bastard mortars such constructions would not have been planned, still less carried to successful completion. The discovery, or rather the invention, of Portland Cement is another example of one of the most valuable contributions to the useful arts, having been made by a person whose surroundings would hardly seem to direct him to such a result. An invention depending entirely on complex chemical reactions, that has revolutionized the engineering world and built up one of the greatest of modern industries, was made by an English bricklayer.

Like other useful and notable inventions, Portland Cement did not at once leap into public favor, but for over thirty years after being discovered attracted little attention, until brought into notice by the publication of the very exhaustive experiments made by Mr. John Grant in order to ascertain if Portland Cement were the proper material to use in the construction of the Thames Embankment and the main drainage works of London.

NOTE.—It is claimed by some authorities that Joseph Aspdin's discovery, as patented in October, 1824, was not that of true Portland Cement, because he fails to indicate in the specifications of his patent the proper proportions of the two ingredients, and because he omits to say that incipient vitrification must be reached in the calcination of the raw cement mixture of lime and clay. But one must be skeptical, indeed, who can read the exceedingly brief but full wording of Aspdin's patent and doubt that he was the real discoverer of Portland Cement, especially when it is a well-known fact that his son William, establishing a manufactory a few years after his father's patent was dated, was one of the earliest producers of true Portland Cement.

The greatest rival of Portland Cement for years was the English "Roman" cement, similar in strength and character to our best American natural cements, such as the "Rosendale," "Louisville," "Milwaukee," "Allentown," etc., and, like them, made by simply burning the stone containing the proper ingredients and grinding the clinker.

Like our natural cements, as compared with Portland Cements, the "Roman" cement failed to attain an ultimate strength at all comparable with the Portland, and when mixed with the sand the difference between the two in strength was even more marked.

"Roman" cement undoubtedly derived a great deal of its popularity from its name, many people supposing that the cement was similar in its composition to that used by the Romans in building the wonderful roads, aqueducts, town walls, etc., which were found scattered over the countries they conquered, and which still survive the destructive agencies of nineteen centuries. It is considered probable that the inventor of "Roman" cement so named it from sharing in this belief.

It is a curious coincidence that these two rival cements for favor in England during nearly half a century should have had names so strangely misleading.

In reference to the old Roman mortars and to those of antiquity generally, it may seem a little startling to state the fact that, with all the advantages they have had in hardening slowly from two to three thousand years, probably none of them is equal in strength to good Portland Cement mortar made of one part cement and two parts sand *one week old*.

In remote antiquity, before the Roman era, the builders of the Pyramids,* and of the ancient cities whose ruins are dug up from time to time all over the world, depended for strength and durability upon the extreme accuracy with which they dressed the surfaces of the large stones which were to be placed in contact, and also upon the bronze dowels uniting them. No cement mortar was used.

With the Romans, besides accurate stone-cutting, two kinds of mortar were in general use throughout Italy and in the Roman provinces. For domestic purposes, where it would not be exposed to the dissolving action of water, carefully prepared lime mortar was used, while for their moles, quay walls, drains, cisterns, aqueducts, etc., a hydraulic cement, composed of "puzzuola" mixed with fat lime and sand, was used. This cement is quaintly described

* Professor Hayter Lewis mentions bringing "from Egypt a portion of the mortar used in the great Pyramid, which was at least five thousand or six thousand years old. It was quite friable, and therefore it was evident that it was not age which gave strength to the Roman mortar." The mortar mentioned by Mr. Lewis must have been an inferior lime mortar, and, of course, not to be compared with the strong Roman mortars made from both lime and "puzzolane" cements, which were unknown when the Pyramids were built.

by Vitruvius, in the second book of his work, in the fourth chapter, as follows :

"In the vicinity of Bajä, and near the towns that are situated in the neighborhood of Mount Vesuvius, one finds a kind of dust which produces curious things. Mixed with lime, this dust does not alone give great strength to buildings, but, more astonishing still, it does the same to water structures. In a very short time the walls that are built in the sea connect with one another, and get so hard that no flood nor other power of the water is able to destroy them."

As, quite contrary to the popular theory on this subject, the strength of the old Roman puzzolane mortars never equalled that attained by mortars made from our Portland Cement of the present day, so is the popular idea a fallacious one that the composition of the old mortars is a lost art. On the shores of the bay of Naples puzzolane mortars are still made and used, very nearly the same in composition as they were in the days of Vitruvius, and it was this material—puzzolane, or its equivalent, trass (almost identical in its composition)—that supplied Europe with hydraulic cement for the long period prior to the introduction of the Portland. Puzzolane has also made possible the extensive and successful submarine constructions of the Italian and Dutch engineers. Between the years 1850 and 1860, before Portland Cement had come into general use, quite an acrimonious controversy was carried on by the French engineers, and published from time to time in the "*Annales des Ponts et Chaussées*," in relation to the capability of mortars made from the natural puzzolanos of resisting the disintegrating and dissolving action of sea water, and it was contended on one side that these mortars were not capable of resisting the action of sea water, notwithstanding the Roman works of similar character still standing on the shores of the Mediterranean, and the Dutch works in the Low Countries, about which there could be no dispute. The whole discussion was very similar in tone to that prevailing in some engineering circles of the present day in relation to the alleged failure of the Portland Cement to resist sea water, as shown by the results in its use in the construction of such works as the Aberdeen graving-docks, whose partial failure has been an eloquent theme for the opponents of Portland Cement.

Since Portland Cement has now established itself so firmly in the popular favor, both by the improvement and excellence shown in its manufacture and by the lowness of its cost, the price in this country having fallen more than fifty per cent. within the last fifteen years, and its strength, when mixed with sand, having been nearly doubled in the same time, the most important point now to be considered next to the character of its manufacture is the method according to which it shall be tested.

In the testing it is the same as in the using of Portland Cement, a very little unskillfulness or inexperience will give bad results for the best quality of cement manufactured. It is clearly so much in

the interest of the consumer as well as of the manufacturer that some standard, uniform method of testing cement should prevail, that it may be said to be a necessity, and yet in several of the largest countries where Portland Cement is used no such standard exists. Germany is entitled to the credit of having led the way in establishing a cement standard, and her example has been followed by Austria, Sweden and Russia. The working results of these systems, now over ten years old, while perhaps they have not realized all that the most sanguine have claimed, have been very satisfactory.

In England and through her extensive colonies, in France and the United States, no official standard of testing prevails, and for this strange apathy on such an important subject, probably the United States is the most excusable, and the nearest to the enjoyment of a cement standard, although it may not be an official one. In both England and France, as in Germany, the government exercises a supervision almost personal over private business and manufactures, and this would seem to make the path easy for the establishment of a uniform system of testing. In the United States, on the contrary, the supervision and regulations existing in foreign countries over private enterprises would hardly be tolerated. But while we have no official standard for cement testing here, as in Germany, a great improvement was made in the recommendation of a system, although the standard was omitted, in the Report of the Committee of the American Society of Civil Engineers on a uniform system for tests of cement, made January 21st, 1885. The system for testing cement recommended by that committee has been gradually adopted by different public works throughout the country and incorporated in the cement specifications of our leading engineers, and promises in time to be the standard system for the United States. As the American system of testing becomes more firmly fixed in this country, it will probably lead to the establishment of standards of tensile strength for the seven or twenty-eight day periods in the same manner as the system itself has been introduced. Whatever standard is adopted here, it should be less for the same period than the corresponding German standard, as the two systems of mixing the mortar are essentially different, the German method tending to give higher results.

In the American system* more water is used in mixing the mortar than in the German official test, the American rule being that the mortar "should be stiff and plastic," whereas in the German test it is made like damp earth, with very little plasticity.

The American mode of testing by making the mortar plastic has the following advantages: First, mortar of a plastic consistency is more like the condition in which it is used in actual practice, and the strength deduced therefrom is more valuable as a guide to the engineer than the higher results obtained from the German method.

* See Appendix, page 23.

In the second place, the plastic mortar does not admit of various degrees of consolidation in the moulds by ramming to the same extent as the stiffer mortar does, and this circumstance eliminates a good deal of the unequal personal equation or treatment that is so much to be desired in testing cement. For the same reason, it is much preferable to have the mortar or cement paste for testing purposes mixed in a machine than to have it made by hand, and this is now considered the best practice both in England and Germany, and will doubtless soon prevail in this country. From these remarks it must not be understood that the testing of cement is other than laboratory work, for all attempts to popularize cement testing so that it can be brought within reach of all who use it have signally failed. Cement tests, to be of any comparative value, will always have to be made by persons accustomed to accurate methods, and possessing a considerable degree of experience and skillfulness in this particular line of physical research, which is only to be acquired by long practice. No great equipment of scientific education is necessary for the cement tester; but, on the other hand, he must have a large amount of accuracy and practical experience, with the conscientiousness that will prevent him from slighting or slurring over details in order to obtain results. In this connection, it may be stated that when a standard system of cement testing was agreed upon by the engineers and manufacturers of Germany and Austria, official stations for testing cement under the standard system were established at Berlin, Munich, and other chief cities on the Continent. These stations are in charge of highly-educated officials, generally chemists, and are equipped with all the most improved testing and scientific apparatus. Through the experiments and researches made at these stations, the most valuable contributions to cement literature have been made. Desirable as would be the establishment of similar official government cement testing laboratories in the United States, it does not at present seem possible, for the same reasons that have been given as preventing any connection between the government and the adoption of a standard system of testing cement. In Germany strong efforts have been made to have regulations at these testing stations which should fix higher prices for cement which exceeded the requirements of the standard test, so that Portland Cement should be officially valued according to its quality. These efforts have not yet been successful, and the best manufacturers of Portland Cement are still obliged to see their cements sold for about the same price as inferior cements—a condition of affairs that would certainly seem to warrant some change. The German system of testing, and the American, as far as it has been tried, have worked satisfactorily, and have been extremely valuable in good results as compared with those countries where no systems prevail. The principal difference between the American and German systems is in the greater amount of water used in mixing the mortar in the American system, and consequently the greater degree of plasticity obtained and lower results

in tensile strength.* This difference in formulating the two systems may have been due to the composition of the two committees that made the rules. The American committee was composed of eight civil engineers and one manufacturer, and the German committee of engineers, architects, contractors, and manufacturers, the latter class undoubtedly advocating a system of testing that would give the highest results. The engineers' and consumers' views of this subject—and it should be the manufacturers' also—is that the system of testing adopted, and the various details thereof, such as the shape and size of briquette, different clips, testing machine, etc., make very little difference, *provided all use the same*; and although a slight change in any of these details may vary the results of the tests as much as fifty per cent., once adopted, it does not make any essential difference to any of the interests involved, inasmuch as it is fair for all. After the system has been decided upon, the establishment of standards under this system for fineness, tensile strength, etc., by which the cement shall be accepted or rejected, involves quite another question, and here the manufacturer who is making a superior cement can fairly claim that these standards shall be fixed as high as possible, so as to exclude inferior brands. And this is exactly what happened in fixing the German standards. Certain German manufacturers who could easily produce high-class Portland Cements asked for higher tests, whilst others were satisfied with 142 pounds per square inch, as prescribed by the established rules in 1877. Some of the protesting manufacturers guaranteed a minimum strength per square inch of 227 pounds, and others guaranteed

Dr. Michaélis, the German cement authority, in the Minutes of the Proceedings of the Institution of Civil Engineers, Session 1879 to 1880, makes the following statement to contradict the popular idea that, by lessening the quantity of water used in mixing, the tensile strength of the cement mortar is thereby increased. He says: "No idea could be more erroneous than that the less the water used, the stronger would be the cement. Cement could be spoiled by a deficiency of water as easily as by an excess. While one cement might give the highest results with 18% (by weight) of water, and was totally destroyed by adding only 17 or 16% of water, another by no means quick-setting cement might be completely spoilt by adding 22% of water, because it required 24% of water to attain a high degree of strength."

The above statement requires an explanation, because at first sight it seems to prove fallacious a proposition that is known to be true by every practical cement tester, and it does this by simply stating another well-known fact that does not, however, disprove nor conflict with the popular and correct idea that, by diminishing the water in mixing, the strength of the resulting cement mortar is thereby increased. Of course it is well known that, after a certain point is reached, diminishing the water any further lessens the strength, because there is not enough to enable the chemical reaction or the semi crystallization (that takes place as soon as the cement is moistened) to extend throughout the mass. But as all the cement testing is supposed to be done by experienced persons, especially in Germany, there is not the slightest reason for the water being reduced beyond the beneficial limit, as the proper amount for mixing should be first determined by experimenting on a small sample.

300 to 350 pounds per square inch, all referring to mortars one part cement, three parts standard sand, twenty-eight days old, the tensile strength of which, by the German rules in 1877, was fixed at 113.8 pounds per square inch, in 1878 at 142.2 pounds per square inch, and in 1887 at 222.5 pounds per square inch. It is therefore evident that there are quite a number of cement works that can make Portland Cement much stronger than required by the German rules, and, as mentioned before, it would seem only equitable to have this excess of strength officially valued and graded, the same as is now done with other articles of trade. The following recommendations, tending to encourage cement manufacturers to make still further improvements in the strength of their cements by helping them to get higher prices for them when so improved, are contained in the German rules of 1878: "Cement of higher tensile strength than ten kilogrammes per square centimetre (or 142 pounds per square inch) in most instances permits of a larger addition of sand. From this point of view, and often even on account of its greater strength, if mixed with equal proportions of sand, it is entitled to a higher price in proportion."

The standard that now seems most likely to be adopted in the United States by which cement shall be accepted or rejected will be one similar to the sand test of Austria, adopted in 1878, for the two periods of one week and twenty-eight days. Having the two periods is of great convenience on work where there is not sufficient storage room to keep the cement twenty-eight days awaiting the results of the test. In this case the shorter period test would generally govern, and the cement could be safely used on passing it. If the cement failed on the seven-day test, it should be set aside to await the result of the twenty-eight day test before definitely rejecting it.

In relation to supplanting the neat test by that of the cement mixed with three parts of standard sand, it is quite curious to note the reluctance with which the most prominent cement engineers give up the neat test, while acknowledging the many advantages over it possessed by the sand test.

Mr. John Grant says: "Nothing has done so much to raise the quality of cement in Germany as the adoption of the system of testing its strength when mixed with three times its weight of sand of a standard gauge and quality, and made into briquettes, which are tested when twenty-eight days old. To give a clue to any cause of discrepancy or disappointment which may arise, and for experimental purposes, it is desirable to ascertain its weight, degree of fineness, time of setting, and, where there are facilities for it, the chemical character and other features of cement. But if it give the required strength when mixed with sand after four weeks, it may be accepted without fear, and the specification is much simplified." Mr. Grant also adds, referring to himself: "The author has for several years past used the test of cement with sand, and would have adopted it long before he did but for the occasional and temporary difficulty it involves at the commencement of works carried

on in public thoroughfares—of waiting a month to know the results. This can, however, in most cases be got over, either by making early arrangements for getting the cement by a tentative test at seven or fourteen days, or by other methods, approximately ascertaining the quality of that which has to be first used; but no cement should be rejected before the test at twenty-eight days has been made."

"Numerous experiments by a great number of observers in different countries have shown beyond dispute that heavy, well-burnt cements, which, when tested neat, have given high results, have, notwithstanding, when mixed with sand, turned out disproportionately weak. Even when the important test of fineness is coupled with that of weight, the strength of cement when tested neat does not always correspond with its strength when mixed with sand. The only thing wanting to make this (sand with cement) test perfect is time—*i. e.*, to be able to wait for the results months instead of weeks." And again: "It was agreed that the test with sand was the most important. This was proved beyond doubt by several of the tables in the Appendix ('Portland Cement: its Nature, Tests and Uses,' Paper No. 1700, by John Grant. Excerpt Minutes of the Proceedings of the Institution of Civil Engineers, Session 1879-1880), which showed that the test of neat cement alone would lead to great errors, reduced, no doubt, but not eliminated, by coupling it with the test for fineness. *Still, the neat test had its uses, and he had always retained it, though he no longer depended upon it.*" In view of Mr. Grant's own statement as quoted above, it is difficult to see why he still retains the neat test, although "he no longer depends upon it."

Dr. Michaëlis, the German authority on cement, is not much more convincing than Mr. Grant, in the reasons that he gives for still using the neat test, in the same discussion from which Mr. Grant has been quoted. Dr. Michaëlis says: "If the question was raised as to testing cement neat or mixed with sand, and if it were acknowledged that only one of these two methods was permissible, then there was no doubt that the decision must be in favor of the sand mixture. It was only when mixed with sand that one of the most important properties of cement could be appreciated, namely, its power of uniting other substances. This was totally distinct from its strength, and depended chiefly upon fine grinding, which was of primary importance. Fine grinding was the only rational method of utilizing the cement to its fullest capacity." And again: "The next question was whether it was right to go from one extreme to the other by giving up the test with neat cement, which had so long been customary in England, and by substituting for it the test with sand. From the commencement Dr. Michaëlis had been of the opinion that the proper course lay between the two. It was the test with neat cement alone that indicated what proportion of water was the most favorable for the particular cement under examination." And again: "It was a mistake to think that the

test made with sand according to the German standard rules give more regular and uniform results than briquettes made in the same way with neat cement. A method of carrying out the latter test could quite as easily be prescribed as for the sand mixtures. He would recommend the retention of the test with neat cement."

Mr. Henry Faija is also in favor of the neat test, although he does not agree with Messrs. Grant and Michaëlis in the value which they attach to the sand test. He says: "The principal objection to the sand test, however, is the difficulty of manipulation. It is hardly skill and knowledge of cement which enables a manipulator to obtain a good result from a sand briquette; it seems to be a peculiar knack, impossible to teach, which some possess and others can by no amount of practice acquire. It is further questionable if the sand test gives any better guide as to the value of the cement for practical purposes than the three and seven day's neat test, for it will be readily admitted that a standard sand is an impossible sand to use in practice."

The above quotations from those who are justly considered as among the highest authorities on cement subjects, show how much opposition there is to abandoning the neat test in favor of the sand test, and yet the change has been made in Germany and will probably some day be universally adopted. In this connection it may be mentioned that the chemical analysis of Portland Cement should go hand in hand with the testing, and if some simple and quick method were devised to determine either the principal or the objectionable chemical constituents of cement, the slow determination of its value by obtaining the tensile strength at the end of 28 days might then be anticipated. Very little experimental chemical work in this direction has been done either in England or the United States, and such chemical knowledge and literature as we now possess of Portland Cement is mainly the result of researches made in this field by German chemists. In relation to the need of a chemical as well as a mechanical test, the following remarks are very interesting and were appropriately made by Mr. Harrison Hayter, Vice-President of the Institution of Civil Engineers, in the discussion published of the Session 1886-1887, Part No. 1, on concrete work for Harbors. He says: "In all the works described, Portland Cement concrete has been adopted, and nowhere throughout the papers was it apparent that there had been any failures. He had been engaged for many years in the construction of harbor, dock and other works, where Portland Cement concrete had been exclusively used under a variety of conditions. Hitherto he had been in the habit of regarding Portland Cement as infallible, so little trouble had it given. This material has now practically superseded all other cementing materials, such as Roman Cement and lias, and other hydraulic limes. Indeed, without Portland Cement, the works described in the papers could not have been constructed at all with concrete, and probably some of them would not have existed, as the cost would have precluded their construction, but in the last year or

two he had met with failures in Portland Cement used in concrete in public works. The cement in every case had stood the ordinary mechanical tests, the sand and shingle had been good and the concrete had set as hard as usual. But after a time expansion had set in. In one case a vertical wall about 35 feet high had lifted about two and one-half inches; in another a mass of concrete 16 feet thick had lifted from one-half inch to one and one-quarter inches. In a wall the first appearance of expansion was indicated by cracking, followed by pieces flaking off the face, and the evil extended, until the concrete might be at last destroyed. In every case a white substance of the consistency of cream was seen in the concrete. These occurrences, so different to what he had hitherto experienced, puzzled him much at the time. His attention, however, not long ago had been directed to an article on this subject by Mr. G. L. Lechartier, published in the 'Comptes Rendus des Séances de L'Académie des Sciences,' Paris, of the 31st May, 1886. Mr. Lechartier alluded to many failures of works of all kinds in which Portland Cement had been used in some form, all constructed by competent engineers or architects, and in which every care seemed to have been taken. Indeed, so many failures had been referred to, that Mr. Hayter began to think that they were more common in France than in England. But he had since found that they were more frequent here than he had supposed. In all cases Mr. Lechartier had detected magnesia in structures that had failed, and sometimes in large quantities. Mr. Hayter had an analysis made of this cream-like substance, and it was found to contain 80% of magnesian hydrate, consisting of about two-thirds magnesian oxide (magnesia) and about one-third water. He also had the concrete analysed that had failed, and in every case magnesia was present. Indeed, in one specimen of concrete there was so much of this substance, that the chemist thought the cement had been made from dolomite, not from chalk as an ingredient, but this was not the case. He believed the composition of good Portland Cement should be Lime, 50%; Silica, 30 to 35%; Alumina and Oxides of Iron, 13 to 15%. In all cements there were other ingredients in small quantities, including magnesia, the quantity of which should on no account exceed 1%. Magnesia in Portland Cement did not prevent the ingredients setting and the concrete becoming apparently as hard as though it were absent; for a time it remained inert when in the mixture, and for months it might be there was no apparent alteration. The magnesia, however, had an affinity for water; every two pounds of magnesia in becoming hydrated, took up and solidified one pound or 27.7 cubic inches of water, and in bulk, every ton of magnesia would have to find room for about 18 cubic feet of water. It was in finding room for this water that the concrete became disintegrated. The action went on whether the concrete was in air or in water, but as might be expected, more rapidly in water; in the former case it became hydrated by the slow absorption of moisture from the atmosphere. Another substance in Portland Cement which was injurious,

but in a less degree than magnesia, was carbonate of lime. In adding water to the cement, a crystallized double silicate of lime and alumina was formed. But if there was too much lime in the cement it was not taken up by the silica. It did not prevent the setting, but after a while the free lime absorbed carbonic acid from the atmosphere and was converted into a carbonate of lime, which remained inert in the cement and weakened it. Some cement which had been analysed for him, contained as much as 12% of carbonate of lime. His object in making these remarks was *to point out the necessity of a chemical as well as a mechanical test* for Portland Cement used in concrete or mortar. This did not seem to have been introduced generally in this country. In his opinion the mechanical tests usually adopted were too high. It was discouraging to an engineer when he had done his best to insure good material and workmanship, to find after the lapse of a limited period, concrete work executed by him began to show signs of failure. Such an occurrence was apt to throw discredit on an engineer, even though failure might arise from causes which he could not foresee. It would be to the interests of engineers and manufacturers to do what they could to protect themselves in this respect. The conclusion to which he had arrived as regarded the use of Portland Cement in concrete or mortar was: First—*That the general introduction of a chemical test as well as a mechanical test for Portland Cement was most desirable.* Secondly—That the ingredients entering into the composition of Portland Cement should be generally in the proportions he had referred to above, which would ensure a good cement if properly treated in manufacture, and also that it should contain no carbonate of lime. Thirdly—That no Portland Cement containing more than 1% of magnesia should be used. He believed that manufacturers would gladly accept these rules, for he had invariably found them desirous to raise as much as possible the standard of the article they supplied. *In Germany a chemical test as well as a mechanical test was the rule and not the exception."*

The above remarks of Mr. Hayter give a very good idea of what is required in England and this country at the present time to make the use of Portland Cement in submarine work successful in every case.

The average proportion of the principal constituents that the analysis of a good Portland Cement should show are: Lime, 60%; Silica, 24%; Alumina and Iron Oxides, 12%. The percentages given by Mr. Hayter place the Lime too low and the Silica too high. Sulphuric acid is also an objectionable constituent in Portland Cement not mentioned by Mr. Hayter. By the rules of the "Ecole Nationale of Paris," if the sulphuric acid exceeds one and one-half per cent., the cement is rejected on the chemical analysis alone. We have, therefore, three chemical constituents found in Portland Cement that become very objectionable when they exceed certain percentages, namely: Magnesia when in excess of one per cent. and carbonic and sulphuric acids when either of them exceeds one

and one-half per cent. Cements found by chemical analysis to contain magnesia, carbonic or sulphuric acid in excess of the percentages given, could be rejected at once, without waiting for the slow results required by the mechanical tests. On the other hand, cements giving satisfactory chemical analyses are not necessarily either sound or strong cements, the chemical analysis giving very little indication of the tensile strength of cement and is very liable to be at fault in showing the amount of free lime present. The free or uncombined lime is usually determined by finding the amount of carbonic acid and calculating the amount of free lime present as carbonate of lime. This method is faulty in theory and gives poor results in practice. Before all the free lime present in a barrel of cement can become carbonate of lime it must first be hydrated by absorbing moisture and afterwards carbonated by absorbing the carbonic acid from the atmosphere. These two processes are necessarily slow, and with a tight barrel well packed and lined with water-proof paper, they may take months and even years before they are completed. In the portion of the cement forming the sample that is actually subjected to the chemical analysis, the hydrating and carbonating of the free lime might be artificially hastened by placing the sample first in a moist atmosphere and then in one of carbonic acid; but this is not usually done, and even then the chemical determination of free lime would not be as satisfactory as to find it mechanically. The subject of free or uncombined lime has been referred to at some length because of its importance, as the writer thinks that many of the Portland Cement concrete failures that have been attributed to an excess of magnesia, have, perhaps, been caused by free lime in objectionable quantities. Until some better method, than those in present use to determine free lime by chemical analysis, is found, reliance will have to be placed on the mechanical determination by moulding small flat pieces or pats of the pure cement and noting any change in volume after the cement has set hard and after the pats have been subjected to various conditions relating to the temperature and immersion.

By the new German rules, the treatment of these pats, as tests to indicate change in volume in Portland Cement, is that they shall be immersed twenty-four hours after gauging. It is the experience of the writer that by keeping the pats in air twenty-four hours after gauging, they are made of very little use in detecting free lime or change in volume.

On the other hand, by immersing these pats as soon as they are hard, as recommended by the American rules, much better results are obtained; but the best practice is to expose the pats as soon as they are hard for about three hours to a high temperature saturated with moisture and then slowly boil them for about twenty-one hours. The recommendation usually given to purge Portland Cement of an objectionable amount of free lime, is to lay it down on dry floors in thin layers for three or four weeks until the free lime has become air-slaked.

This process of getting rid of free lime is a very uncertain one, depending on the thickness of the cement layers and the moisture of the surrounding air. As by some authorities it has been recommended to spread the cement which is to be purged to a depth of four feet on the floor, the air-slaking of the cement in this case would be exceedingly slow and not uniform throughout the mass. In fact, as the presence of free lime in Portland Cement in objectionable quantities makes the cement unreliable and treacherous in the highest degree, and as the purging of this free lime by the air-slaking process is very uncertain in its action, it would be much better for all interests to have the cement more carefully manufactured, so that the free lime would not be present much in excess of about 2%; or in the case of a greater quantity being found to be present, the purging process by air-slaking in thin layers should take place at the factory, where the operation can be properly watched and careful tests made from time to time.

These tests should determine if the free lime has absorbed moisture enough to render it inert, or if the cement contains too much free lime to be properly hydrated, the cement should be condemned. Theoretically, good Portland Cement should not contain free lime in excess of about two per cent. (shown by the carbonic acid not exceeding about one and one-half per cent.), and when cement is found to exceed this percentage, it has become too common for Engineers to consider this excess with complacency. Instead of at once condemning the cement as being poorly manufactured, they proceed to apply the "air-slaking" or "purging" process, as if it were possible by imperfect methods in practice to correct radical defects in the manufacture.

The whole subject of free lime is exceedingly important just now, in view of the fact that in England, within the last twenty-five years, the average standard for the tensile strength of Portland Cement has more than doubled, and when it is considered that the heavily limed slow setting cements are invariably the strongest, the constant tendency in the manufacture of Portland Cement to-day is in the direction of making a cement with a large proportional quantity of lime, as compared with the clay, and in consequence there is always a danger of containing an excess of free lime.

Indeed, there should be a little question in assigning a cement of great tensile strength at the end of 7 and 28 days and containing an objectionable amount of free lime, to an inferior place as compared with a cement of perhaps less tensile strength but perfectly sound in respect to free lime, magnesia and sulphur. To those who are accustomed to estimate the value of Portland Cement principally by the tensile strength, at the end of 7 and 28 days, with the cement gauged neat, it may seem a little strange that a cement containing an excess of free lime should not show a diminution in its tensile strength at both the 7 and 28 day periods, simply from the prejudicial action of such free lime in retarding the setting process and thereby lessening its comparative strength. Nevertheless such an

anomaly does exist in Portland Cement, and in the writer's experience the worst cases of free limed cements have given normal tensile strengths at the 7 and 28 day periods, gauged neat and with two parts sand. Dr. Michaëlis claims that if the cement is gauged with five parts of sand, the presence of free lime in large quantities or in quantities sufficient to cause the cement to "blow," will be shown by a diminution in the tensile strength of such mortar. He says "the cementitious value and trustworthiness of cement were more evident with 1 to 5 (sand) than with 1 to 3 (sand). Among more than 80,000 experiments it never occurred that good results* were obtained in seven or twenty-eight days in any case where the cement had a tendency to 'blow.' This might, however, happen with the proportion 1 to 3, deterioration taking place subsequently.

No cement with any tendency to blow, however slight, would give a favorable result if tested in seven days. If the cement showed a high strength neat, it proved that the sample was highly burnt; if the mixture with five parts of sand gave high results, it indicated that the cement was *faultless* and finely ground."

The above opinion of Dr. Michaëlis has been partially confirmed by results obtained in the writer's practice, and we have, therefore, two reliable mechanical methods to determine if a cement contains sufficient free lime to injuriously affect the work in which it is used. First—The short method by treating the pats of hardened cement to moist air and boiling water; and secondly, the longer method, by finding the tensile strength of mortar of one part cement with five parts sand, for the seven and twenty-eight day periods.

To these two indirect mechanical determinations will undoubtedly be added a third by chemical analysis, whenever the methods for finding free lime directly thereby become more reliable.

After a Portland Cement has passed all the requirements exacted by the modern systems of testing briefly referred to in the preceding pages, its value may be seriously impaired and in some cases destroyed by ignorance and unskilfulness on the part of those into whose hands it falls to use it.

Concrete made with the best Portland Cement may have its strength reduced as much as one-half and sometimes more by the following objectionable treatment, which practices, however, except in the last two cases mentioned, have been sanctioned by some of our leading Engineers in this country and in Europe.

First—By *heating the materials* for making concrete in freezing weather, when the concrete is to be deposited either under water or out of water.

Second—By *adding salt to the materials* for making concrete in freezing weather, when the concrete is to be deposited either under water or out of water.

Third—By *adding lime to the materials* for making concrete,

* Tests of mortars 1 to 5 sand are here referred to.

except in the case when Portland Cement is mixed with a large quantity of sand, as in the proportion of 1 to 7 sand, where a little lime added makes the mortar more unctuous, although this quality is always obtained at the expense of the tensile strength.

Fourth—By *breaking up the initial set of the cement* after the concrete has once been mixed and has begun to harden and to lose its plasticity.

Fifth—By *not providing for expansion and contraction* in monolithic concrete work by placing vertical joints at regular intervals transversely to the longest dimension.

Sixth—By *mixing Portland Cement with fine or loamy sand*.

Seventh—By *badly proportioning the materials* forming the concrete or by loosely describing this proportion in contracts for concrete work, as so much cement to so much ballast, instead of accurately defining the composition of the mortar first, and then giving the amount of the mortar that should be mixed with the aggregate.

Eighth—By *mixing the materials for concrete with too much water*.

Ninth—By allowing the freshly mixed or plastic concrete to be badly washed in passing it through water to the place where it is to be deposited.

In relation to the alleged failure of Portland Cement in the Aberdeen Graving Dock, which was so extensively advertised in 1887, in all cement circles, there is a great deal to be said on the side of regarding the failure of the wing walls of the dock as having arisen from causes that were avoidable, and that it was not due to the simple fact that Portland Cement was used and that it was chemically affected to an injurious extent by the action of sea water.

First—The wing walls (about which all the trouble arose) forming the entrance to the dock, were a very small part of the whole dock, and as they were built dry inside of a coffer dam, the materials for the concrete entering into them could have been accurately and properly proportioned, but this was not done. Even the terms of the contract in regard to the character of the concrete in the wing walls, which failed, were deviated from, for the worse, that is the amount of permeable mortar of 1 to 3 sand, was increased and the amount of impermeable stone was decreased. On this small and important part of the work, because it would be subjected to hydrostatic pressure, when the dock was empty, the mortar should have been 1 to 2 sand mixed with $4\frac{3}{4}$ of stone ballast, instead of 1 to 3 sand and 4 of ballast, which was actually used. By this trifling change, no addition would have been made to the cost, the dock would have stood a better chance of having been made water-tight and no stigma would have been put upon the use of Portland Cement.

* Second—Even with the concrete of the proportions that were used, water-tight work could probably have been made by excessive

care in the ramming or consolidation of the layers and keeping the amount of water in the mortar reduced to a minimum.

Third—Granting the opinions to be true of the consulting engineer and chemists in relation to the deterioration of Portland Cement concrete from the chemical action of the sea water in dissolving out the lime of the cement, the reports all go to show that before this action of the sea water can become injurious, it is necessary for new portions of it to pass through the concrete freely many times. This was also proved by the fact that adjacent portions of the work not under hydrostatic pressure like the wing walls, were not affected injuriously by the sea water. In other words, concrete simply immersed in sea water cannot absorb enough sea water to decompose the cement.

When we consider how few of the many large sea constructions with Portland Cement are under pressure on one side only, and that these can be made safe against the decomposing action of sea water by properly proportioning the materials in the concrete so as to make it water-tight, and by enclosing the work under construction in a coffer dam, we can well afford to think that much of the alarm and anxiety caused by the Aberdeen failure has been without foundation.

Fourth—There does not appear in the record of the tests of the cement that were made, as the work progressed, that any precaution was taken to guard against using a cement containing an injurious amount of free lime, and the reports of the chemical experts when examined, show that the cements used probably contained this injurious excess of free lime. In one case the analysis of the dry cement showing a percentage of 3.60 of carbonic acid, equivalent to 8.18% of carbonate of lime. This would have caused the walls to fail quite as quickly as the action of the lime in the cement precipitating the magnesia contained in the sea water.

APPENDIX.

The following is an abstract of the new German rules for testing and of the system of testing recommended by the Committee of the American Society of Civil Engineers. Of the latter, Mr. Faija, in a paper read December 1st, 1886, says: "In most countries on the Continent of Europe, a uniform system has been devised and put in force by the respective governments, and the report of the Committee appointed by the American Society of Civil Engineers to investigate the matter is a paper which deserves most serious and careful consideration of all persons interested in the subject. Without giving a specification, it supplies all the information necessary to enable each user to draft such a specification as will suit his special requirements, and gives most carefully considered and valuable instructions for the guidance of those who have to carry out the test. If anything in the report is to be regretted it is the modesty with which the Committee put forward as recommendations only, the result of their labors."

NEW GERMAN RULES FOR TESTING PORTLAND CEMENT.

In November, 1878, the Prussian Minister of Public Works issued a series of standard rules for testing Portland Cement, which were adopted by most of the Architectural and Engineering Associations in Germany, and subsequently served as a basis for standard rules in several adjoining countries. At the instance of the Association of German Cement manufacturers, these rules have now been altered and several important modifications introduced. The amended rules were published by the Prussian Minister of Public Works, in July, 1887, and differ from the rules previously in force, as follows:

The time of setting of a slow setting cement is now fixed at two hours instead of one-half an hour.

In testing for expansion, the cake of cement is allowed to set for twenty-four hours before immersing in water, during which period it is to be kept moist and in the shade.

The cement must be ground so finely that not more than 10% residue remains upon a sieve of 900 meshes per square centimetre (5.806 meshes per square inch) and made of wire the thickness of which is one-half the width of the mesh; 100 grams (0.22 pounds) of the cement is to be used for each test.

The strength is ascertained by tensile and compressive tests; the cement in both cases being mixed with three times its weight of sand of a definite size of grain.

The breaking area of the tensile briquettes is 5 square centimetres (0.775 square inches) and the compression tests are made with cubes of 50 square centimetres (7.75 square inches). Tests

with neat cement are to be preferred when Portland Cement is being compared with other hydraulic cements. In order to secure uniformity, it is recommended to use similar apparatus to that in use at the Royal Testing Establishment, at Charlottenberg, near Berlin.

The minimum tensile strength of a mixture of 1 part by weight of slow setting cement mixed with three parts by weight of standard sand, after hardening one day in the air and twenty-seven days under water, is 16 kilogrammes per square centimetre (227.5 pounds per square inch). The crushing strength is 160 kilogrammes per square centimetre (2275.6 pounds per square inch).

In giving the strength of Portland Cement, the time of setting should always be mentioned, the strength of quick setting cement being lower than that of slow setting cements.

The final test of strength is the crushing test in twenty-eight days, the twenty-eight day tensile test being used for ascertaining the quality of the cement as delivered. The seven day test may be used for the latter purpose if the ratio of the seven day strength to that at twenty-eight days has been previously determined for the cement under examination. This preliminary test may also be carried out with neat cement, in which case the strength of the same cement neat at twenty-eight days must be known. The standard sand is obtained by sifting clean quartz sand first through a sieve of 60 meshes per square centimetre (387 meshes per square inch) made of wire 0.38 millimetre (0.0146 inch) diameter, than through a sieve of 120 meshes per square centimetre (774 meshes per square inch) made of wire 0.32 millimetre (0.0123 inch) diameter. The sand which remains upon the finer sieve is that which is to be used for the tests. For each series of tests ten briquettes at least must be broken, the average of the ten numbers obtained being taken as the strength of the cement. In making each five briquettes for the tensile test, 250 grams (0.55 pound) of cement is mixed with 750 grams (1.65 pounds) of standard sand and 100 grams of fresh water (0.22 pound), the whole mass being well mixed for five minutes. The mortar is beaten into the moulds for one minute with a spatula weighing about 250 grams (0.55 pound) until water begins to rise. When the surface has been smoothed with a knife, the mould is carefully removed and the briquette placed in a covered zinc-lined box for twenty-four hours. It is then immersed in water for the remainder of the hardening period. In making these briquettes by machinery, Dr. Böhme's apparatus is used; 180 grams of the mortar is placed in the mould and subjected to one hundred and fifty blows of a hammer weighing two kilogrammes (4.4 pounds). In case of dispute the results obtained by means of the machine are to be considered final.

For the crushing tests Dr. Böhme's machine alone is prescribed, the proportion of water and number of blows of the hammer being the same as for tensile briquettes.

In making the neat tests, 1000 grams (2.204 pounds) of the

cement is mixed with 200 grams (0.44 pound) of water ; but with very finely ground or quick setting cements, the amount of water may be increased.

In giving the results obtained, the proportion of water used must be stated.

All the briquettes must be tested immediately they are removed from the water. In breaking the tensile briquettes, the weight must be added at the rate of 100 grams (0.22 pound) per second.

ABSTRACT
OF
UNIFORM SYSTEM OF TESTS OF CEMENT RECOMMENDED BY THE
COMMITTEE OF THE AMERICAN SOCIETY OF CIVIL
ENGINEERS, JUNE 21ST, 1885.
FINENESS.

The strength of a cement depends greatly upon the fineness to which it is ground, especially when mixed with a large dose of sand. It is, therefore, recommended that the tests be made with cement that has passed through a No. 100 sieve (10000 meshes to the square inch), made of No. 40 wire, Stubb's wire gauge. The results thus obtained will indicate the grade which the cement can attain, under the condition that it is finely ground; but it does not show whether or not a given cement offered for sale shall be accepted and used. The determination of this question requires that the tests should also be applied to the cement as found in the market. Its quality may be so high that it will stand the tests even if very coarse and granular, and on the other hand it may be so low that no amount of pulverization can redeem it. In other words, fineness is no sure indication of the value of a cement, although all cements are improved by fine grinding. Cement of the better grades is now usually ground so fine that only from 5 to 10% is rejected by a sieve of 2500 meshes per square inch, and it has been made so fine that only from 3 to 10% is rejected by a sieve of 32000 meshes per square inch. The finer the cement, if otherwise good, the larger dose of sand it will take, and the greater its value.

CHECKING OR CRACKING.

The test for Checking or Cracking is an important one, and though simple, should never be omitted. It as follows: Make two cakes of neat cement 2 or 3 inches in diameter, about one-half inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with mortar to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by General Gillmore, one-twelfth inch diameter wire loaded with one-quarter of a pound and one-twenty-fourth of an inch diameter wire, loaded with one pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted or if cracks show themselves at the edges, such contortions or cracks indicating that the cement is unfit for use at that time. In some cases the tendency to crack, if caused by the presence of too much unslaked lime, will disappear with age. The remaining cake should be kept in the air and its color observed,

which, for a good cement, should be uniform throughout, yellowish blotches indicating a poor quality ; the Portland Cements being of a bluish-grey color, and the natural* cements being light or dark according to the character of the rock of which they are made. The color of the cements when left in the air indicates the quality much better than when they are put in water.

TESTS RECOMMENDED.

It is recommended that tests for hydraulic cement be confined to methods for determining fineness, liability to checking or cracking, and tensile strength ; and for the latter, for tests of 7 days and upward, that a mixture of 1 part of cement to 1 part of sand for natural cements, and 3 parts of sand for Portland Cements, be used, in addition to trials of the neat cement. The quantities used in the mixture should be determined by weight.

The tests should be applied to the cements as offered for sale. If satisfactory results are obtained with a full dose of sand, the trials need go no further. If not, the coarser particles should first be excluded by using a No. 100 sieve (10000 meshes to the square inch), in order to determine approximately the grade the cement would take if ground fine, for fineness is always attainable, while inherent merit may not be.

MIXING, ETC.

The proportions of cement, sand and water should be carefully determined by weight, the sand and cement mixed dry, and all the water added at once. The mixing must be rapid and thorough, and the mortar, which should be stiff and plastic, should be firmly pressed into the moulds with the trowel, without ramming, and struck off level ; the moulds in each instance, while being charged and manipulated, to be laid directly on glass, slate or some other non-absorbent material. The moulding must be completed before incipient setting begins. As soon as the briquettes are hard enough to bear it, they should be taken from the moulds and be kept covered with a damp cloth until they are immersed. For the sake of uniformity, the briquettes, both of neat cement and those containing sand, should be immersed in water at the end of 24 hours, except in the case of one day tests. Ordinary fresh clean water having a temperature between 60 and 70 degrees F. should be used for the water of mixture and immersion of samples.

The proportion of water required varies with the fineness, age or other conditions of the cement and the temperature of the air, but is approximately as follows :

For briquettes of neat cement : Portland about 25%.
Natural cement, about 30%.

* Where the word " Natural " is used in this paper, it is to be understood as being applied to the lightly burned American or foreign cements, in contradistinction to the more heavily burned Portland Cements, either natural or artificial

For briquettes of 1 part cement and 1 part sand, about 15% of total weight of sand and cement.

For briquettes of 1 part cement, 3 parts sand, about 12% of total weight of sand and cement.

The object is to produce the plasticity of rather stiff plasterer's mortar.

An average of 5 briquettes may be made for each test, only those breaking at the smallest section to be taken. The briquettes should always be put in the testing machine and broken immediately after being taken out of the water, and the temperature of the briquettes and of the testing room should be constant between 60 and 70 degrees F.

[NOTE.—Your committee thinks it useful to insert here a table showing the average minimum and maximum tensile strength per square inch which some good cements have attained when tested under the conditions specified elsewhere in this report. Within the limits given in the following table, the value of a cement varies closely with the tensile strength when tested with the full dose of sand.]

American natural cement, neat :

1 day, 1 hour or until set, in air, the rest of the 24 hours in water, from 40 to 80 pounds. 1 week, 1 day in air, 6 days in water, from 60 to 100 pounds.

1 month (28 days), 1 day in air, 27 days in water, from 100 to 150 pounds.

1 year, 1 day in air, the remainder in water, from 300 to 400 pounds.

American and foreign Portland Cements, neat :

1 day, 1 hour or until set, in air, the rest of the 24 hours in water, from 100 to 140 pounds.

1 week, 1 day in air, 6 days in water, from 250 to 550 pounds.

1 month, (28 days), 1 day in air, 27 days in water, from 350 to 700 pounds.

1 year, 1 day in air, the remainder in water, from 450 to 800 pounds.

American natural cement, 1 part cement to 1 part sand :

1 week, 1 day in air, 6 days in water, from 30 to 50 pounds.

1 month, (28 days), 1 day in air, 27 days in water, from 50 to 80 pounds.

1 year, 1 day in air, the remainder in water, from 200 to 300 pounds.

American and foreign Portland Cements, 1 part of cement to 3 parts of sand :

1 week, 1 day in air, 6 days in water, from 80 to 125 pounds.

1 month, (28 days), 1 day in air, 27 days in water, from 100 to 200 pounds.

1 year, 1 day in air, the remainder in water, from 200 to 350 pounds.

DIRECTIONS FOR USING PORTLAND CEMENT.

For certain kinds of work, quick setting cement is not only to be preferred but is almost necessary. This is the case with tide work and with concrete to be deposited in the water.

For all kind of work above water, concrete or mortar made with quick setting cement requires to be put in place and consolidated by ramming before it begins to lose its plasticity. This is not a difficult matter owing to the fact that cement is always used with two or more parts of sand, by which mixture the setting process is greatly retarded.

Most quick setting Portland cements can therefore be used for any work where slow setting cements have been called for ; but slow setting cements cannot be used for tide work, nor for depositing through the water without having a great deal of the cement washed out of the concrete.

Attempts have been made to use slow setting cement for tide work by allowing the concrete or mortar to partially set until the hardening is sufficient to resist the washing out of the cement when it is exposed to the action of the water. But the success that has attended this method of treating cement is not sufficient to recommend it. As a rule, slow setting cement ultimately attains greater strength than quick setting.

Fine or loamy sand or loam mixed with the broken stone for concrete, (where strength is particularly required) should be avoided, as the resulting mortars or concrete are always weakened thereby. There is no objection, however, to using fine sand in the mortar and concrete, in which it is desired to obtain very smooth surfaces and where the strength is not so important ; as in the water tables, window sills and similar portions of buildings ; but loamy sand or broken stone is always objectionable and there can be no excuse for using it without first washing away the loam, as it will always be found more economical to incur additional expense in order to procure good clean sand or broken stone. The finer the particles of the sand used, the weaker will be the resulting mortar up to a certain point, but with loamy sand the mortar is absolutely unreliable, as Portland cement will not bind nor unite clay.

For the same reasons that the sand and broken stone should be clean, all surfaces to be plastered or cemented together should also be carefully cleaned and then dampened. The dampening of the surfaces to which the mortar is to be applied should be especially attended to in brick work and sand-stone constructions in which the material to be cemented is so porous as to absorb a large amount of the water in the mortar necessary for the complete crystallization or setting of the cement, thereby rendering the mortar inert and weak. This fact and the reason for it should be clearly understood and remembered by all users of cement. The hardening or setting process of all cements, whether slow or quick, is essentially a chemical reaction, and the amount of water necessary

for this is taken up at first by the cement, and the surplus water is rejected. If, therefore, after the initial hardening has taken place, the mortar or concrete is exposed to the action of the dry air or heat, some of the water necessary for the continuance of the hardening is abstracted and the mortar or concrete is made weaker. We can therefore lay down the rule to which there are no exceptions, that from the time the water is added all Portland cement mortar and concrete, in order to attain their greatest strength, should be kept in moist air, and as soon as sufficiently hard, they should be immersed in water. If the nature of the work will not admit of immersion, the mortar or concrete should be kept moist for a month after it has been made, *in order to develop its greatest strength.*

MIXING PORTLAND CEMENT MORTAR AND CONCRETE.

There does not seem to be much doubt that Portland cement mortar and concrete can now be mixed more thoroughly and economically in a well designed mixing machine than can be done by hand. But great care is necessary in arranging the machinery to do the work, and no type of machine should be adopted unless it admits of the following three distinct but consecutive operations. First—The dry mixing of the cement and sand in the proper proportions. Second—The thorough mixing of the cement mortar, after the water has been added. Third—The mixing of the cement mortar with the broken stone or gravel.

In most of the concrete mixing machines now in use, the first two operations are performed at the same time, and some machines even are arranged to mix the cement, sand, water and broken stone, all in one operation. Mixing the cement mortar and making the concrete by hand labor is much preferable to using imperfect machinery.

For making the concrete by hand labor, the cement mortar should first be carefully prepared as follows: Spread out on a smooth platform the proportional amount of sand to be used, with one barrel, or with one measure of the cement; add the one barrel or one measure of cement, and thoroughly mix the two until one color is shown; then add the exact amount of water by sprinkling, and thoroughly mix again until the mortar is brought to the state of a stiff plastic mass.

The amount of water necessary to use in order to make a stiff plastic mortar must be ascertained by experiment for each kind of cement, and this is a very important point, as the strength of the mortar is very much weakened by adding a *very* little more water than the necessary amount. It should be remembered, however, that *even* with the same cement, the amount of water necessary to make a stiff mortar varies with the temperature, the degree of moisture in the air, and with the dryness of the sand. If great strength is required, only enough water should be used to make the mortar resemble damp earth, and this when properly rammed in thin layers will show a little moisture on its surface.

The proper proportioning of the ingredients forming the cement mortar or concrete requires quite as much care as their mixing, and can only be done by finding by experiment the amount of voids in the sand and in the broken stone or gravel which is to be employed.

No fixed rules can be given to cover the different requirements and conditions occurring in actual practice, but the following outline may be of service in many cases.

To make a concrete that shall be as dense as the materials will admit of, the voids in the sand should be entirely filled by the cement paste, and the voids in the broken stone or gravel should be entirely filled by the cement mortar. Any excess of the cement paste over the amount required to fill the voids in the sand, and any excess of the cement mortar over the amount required to fill the voids in the broken stone or gravel, instead of being beneficial to the concrete makes it more permeable. This is a point seldom alluded to, and still more rarely provided for in practice, the prevailing opinion being that the more cement that is used in proportion to the sand the denser will be the mortar, and that the more mortar that is used in proportion to the broken stone the denser will be concrete; whereas the reverse is true in either case after passing the point of having the voids filled in the aggregates; and it can be easily proved by experiment that a mortar composed of one part of cement and three parts of sand (properly mixed and where the voids in the sand do not exceed 30%) is less permeable, though, of course, much weaker than pure cement paste.

Where the sand contains about 30% of voids, and the broken stone about 50% of voids, the following should be the proportion of mixing:

Cement	Sand	Broken Stone
I	I	3.4
I	2	4.8
I	3	6.2
I	4	8
I	5	10
I	6	12

In the above table, after passing the proportion of 1 cement to 3 of sand, the voids in the sand would not be filled, and the mortar will be more and more permeable as the sand is increased.

In most English specifications, in describing the composition of concrete, the cement is required to be a certain part of the whole mass, without fixing its relation to the proportion of sand to be used. The method is a very faulty one, and in practice gives rise to many mistakes and poor work.

After concrete has been properly proportioned and mixed, if deposited in work above water, it should be carefully rammed in layers of about 4 inches so as to cover the stone with a film of thin mortar. In very cold weather excellent results can be obtained from Portland Cement concretes, where concrete made with natural cements would

fail entirely. In this case the materials should never be heated, nor should salt be used with the idea of preventing freezing.

As all Portland cement concrete work above water contracts in setting, while under water it expands, provision for this is usually made in monolithic work by placing vertical joints at regular intervals and at right angles to the longer dimension.

The depositing of loose or plastic concrete under water should be avoided, as it is a very delicate operation and there is always the greatest danger of the cement being washed out and the materials being deposited in layers according to their respective specific gravities. Concrete blocks made on shore, coffer dams to enclose the work and to allow the concrete to be made out of water, should be resorted to in preference. If it is necessary to deposit the plastic concrete through the water, it should always be enclosed in bags.

Of late years, one of the most successful applications of Portland cement concrete has been to make the side-walks of cities and towns "in situ." When this industry was first started, there were many failures in the work done, from cracking and from the surface wearing away, leaving unsightly holes. If the following directions are observed, there will be no trouble experienced from cracks nor from wearing away. Compact or ram earth on the site of the side-walk, to a level surface of about 16 inches below the grade of the top of the side-walk, then place small stones, not longer than 10 inches nor thicker than 4 or 5 inches, on end, and slightly inclined, and cover the same with a thin layer of ashes or fine gravel. Turn the traffic of the street on this surface, and, after it is well compacted, cover it with a layer of Portland cement concrete about 4 inches thick and composed of 1 part of cement, 2 parts of sand and 5 parts of broken stone well tamped. On top of the concrete should be placed a mortar, composed of one part of Portland cement and one part of sharp sand, mixed with very little water, and struck off to a very smooth surface with a straight edge. This mortar should be about one inch in thickness and should always be placed before the concrete below it has set very hard. Only the very best Portland cements should be used for side-walks.

Of all the uses to which Portland cement may be applied, that in which it acts as a beam to receive a transverse load is the one to which it is least adapted. Its average strength when mixed with 2 parts of sand, one year old, and used to support transverse loads, is about (1-15) one-fifteenth that of a wooden beam of the same section.

Thus concrete arches have not the strength that is popularly ascribed to them, for the same reason that concrete beams are weak, and great care should be taken in proportioning the materials for them and in supervising their erection.

§FINIS.

"BURHAM"

PORTLAND CEMENT.



This brand, by its thorough uniformity and great strength, is now, and has been for years, the most popular brand of Portland Cement imported into the United States.

Its quality can be thoroughly relied upon, and for any class of work for which Portland Cement is used, it can be earnestly recommended.

The quantity consumed yearly is nearly double that of any other brand.

The following are a few of the large works recently constructed with "BURHAM" PORTLAND CEMENT:

Government Breakwater, at Buffalo, N. Y.

N. Y. & Prov. R. R. Bridge, at New London, Conn.

Government Dry Dock, at Brooklyn Navy Yard.

" " " Portsmouth "

" " " League Island Navy Yard.

Newport News Co. Dry Dock, at Newport News, Va.
Built by J. E. Simpson & Co., N. Y. City.

"Sodom" Dam, at Brewsters, N. Y.

East Park Reservoirs, at Phila, Pa.
D. R. Paige & Co.

Dams 1 and 2, and adjacent Tunnel at Bog Brook.

Cable Railways at Chicago, Ill., St. Paul, Minn., Kansas City, Mo., Denver, Col., and in other cities.

TENSILE STRENGTH,

“Burham” Cement, used in the Construction
of “Sodom” Dam, at Brewsters, N. Y.

TESTS MADE BY MR. GEO. B. BURBANK, DIVISION ENGINEER.

≡≡≡ NEAT CEMENT. ≡≡≡

1 day,	—225	Briquettes.	—Average Strain,	185	lbs. per square inch.		
1 week,	—67	“	“	“	464	“	“
1 month,	—16	“	“	“	615	“	“
3 “	—28	“	“	“	725	“	“
6 “	—10	“	“	“	668	“	“
9 “	—10	“	“	“	725	“	“
1 year,	—10	“	“	“	799	“	“

MORTAR,—2 parts Sand to 1 part Cement.

1 week,	—27	Briquettes.	—Average Strain,	144	lbs. per square inch.		
1 month,	—12	“	“	“	259	“	“
3 “	—18	“	“	“	420	“	“
6 “	—6	“	“	“	372	“	“
9 “	—8	“	“	“	479	“	“
1 year,	—10	“	“	“	659	“	“

MORTAR,—3 parts Sand to 1 part Cement.

1 week,	—34	Briquettes.	—Average Strength,	176	lbs. per square inch		
1 month—	5	“	“	“	297	“	“
3 “	—40	“	“	“	330	“	“
6 “	—20	“	“	“	395	“	“

Fineness through 2500 Mesh Sieve, **95%**

CHEMICAL ANALYSIS.

PORTLAND CEMENT ANALYSIS Nos. 3114 AND 3115.

SAMPLES RECEIVED FROM MR. JAMES BRAND:

MARKED, JOSSON & BURHAM.

	<i>Josson %</i>	<i>Burham %</i>
1. Lime CaO	63.60	61.04
2. Silica SiO_2	22.60	22.45
3. Alumina Al_2O_3	6.72	6.91
4. Oxide of Iron Fe_2O_3	1.69	3.62
5. Magnesia MgO	0.97	1.18
6. Potash K_2O }	1.62	} 1.86
7. Soda Na_2O }		
8. Sulphate of Lime CaSO_4	—	—
9. Water H_2O	—	—
10. Sulphuric Acid,	1.30	1.44
11. Carbonic Acid,	1.50	1.50
	100.00	100.00

The analyses of these two brands of Cement are almost the same, and are both excellent, showing the samples to be true Portland Cement.

The objectionable constituents in a Portland Cement, are:—Magnesia, when it exceeds one per cent., and Carbonic or Sulphuric Acid, when either exceeds one and a half per cent. In neither the Josson nor the Burham analyses are the objectionable elements present in excess.

W. W. MACLAY,

C. E.

“JOSSON” PORTLAND CEMENT.



A SPECIALTY FOR SIDEWALKS.

This Cement is of desirable color, very strong and finely ground. Being chemically a pure Portland Cement, it is not liable to crack, check or scale. For Sidewalk purposes, it is unexcelled.

TENSILE STRENGTH.

TEST MADE BY DEPARTMENT OF DOCKS.

Neat Cement Briquettes, 7 days old, 490 lbs. per square inch.
2 pts. Sand, 1 pt. Cement Briquettes, 7 days old, 179 lbs. per “

Weight per Cubic Foot, 93 lbs.

Setting time, 150 minutes.

Fineness, 97 per cent. through 2500 Mesh Sieve.

TEST MADE BY W. W. MACLAY, M. A.

Neat Cement Briquettes, 28 days old, 489 lbs. per square inch.
2 pts. Sand, 1 pt. Cement Briquettes, 28 days old, 220 lbs. per “

Fineness, 100 per cent. through 2500 Mesh Sieve.

"Safarge"

Portland Cement.

For setting stone fronts of buildings, Granite, Lime Stone, &c., &c., this Cement is specified by the leading Architects, as it is the strongest and finest ground Cement made and does not discolor. "SAFARGE" was used in such buildings as:—

EQUITABLE LIFE INSURANCE CO.'S BUILDING.

MUTUAL " " " "

UNION TRUST CO.'S " "

FARMERS LOAN & TRUST CO.'S " "

TIMES NEWSPAPER " "

WORLD " "

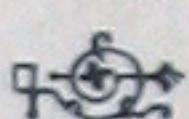
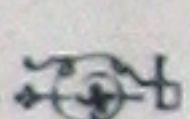
MERCHANTS BANK.

BANK OF AMERICA,

and many others; also used to a large extent for setting Monuments.

For this class of work, it is superior and more economical than any other cement

x x x x x x x x x x x x x

"Burham"	}	 Portland  Cement. 
"Josson"		
"Lafarge"		

x x x x x x x x x x x x x

KEENE'S
 Superfine and Coarse Cements,
 LIME OF TEIL.

x x x x x x

IMPORTER AND SOLE AGENT IN U. S.,

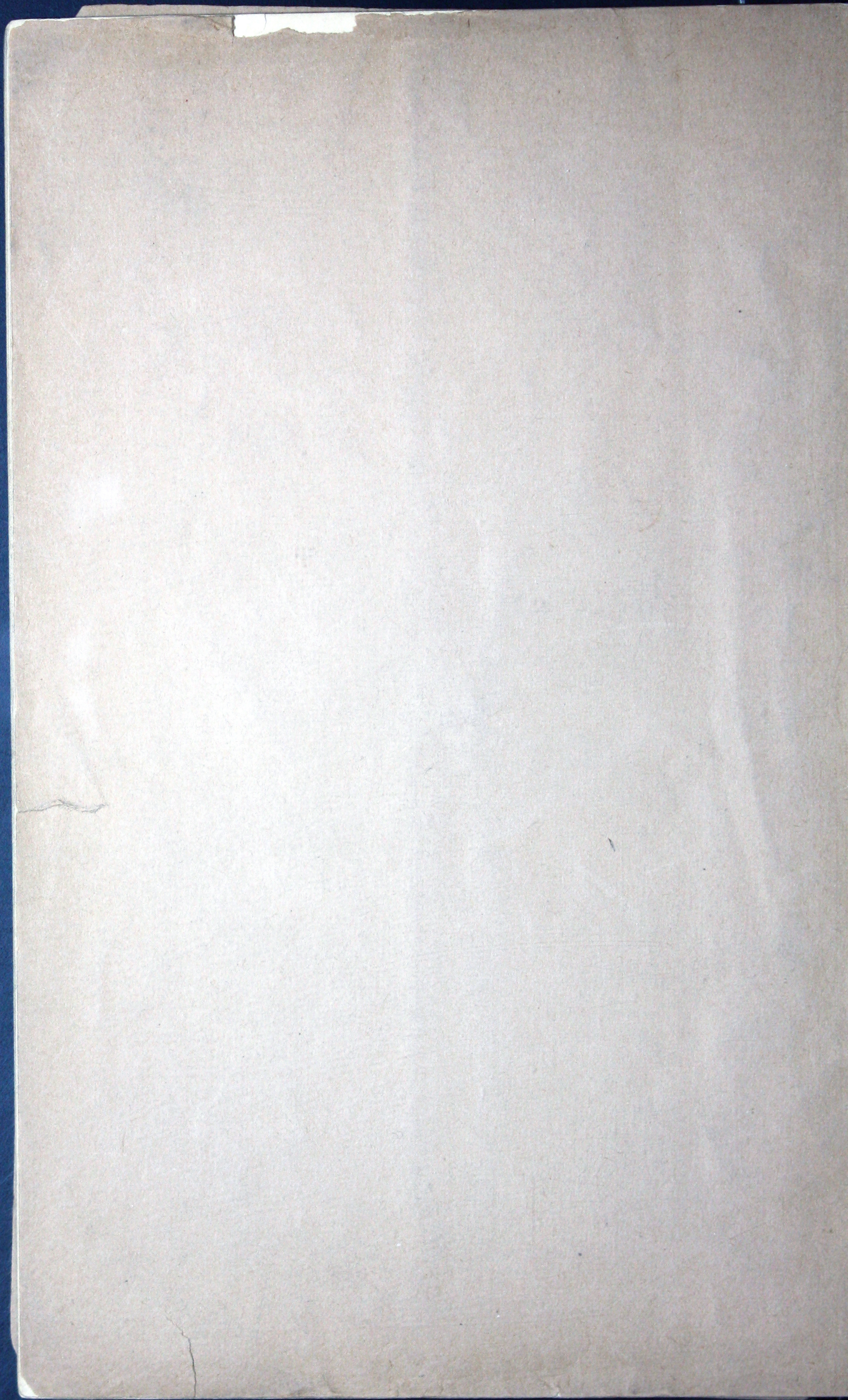
JAMES BRAND,

81 & 83 FULTON STREET,

NEW YORK CITY.

x x x x x x

The above brands can also be obtained from all first class
 dealers in Building Materials.



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